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There has been a significant increase in activity with the military and the airline industry regarding the encouragement and use of so-called 'drop-in renewable fuels'. The USDA and DOE and the U.S. Military, have announced funding of over $500 million for development of 'drop-in renewable fuels' for military and aviation use. While B5 (5% biodiesel, 95% petrodiesel) has been adopted as a 'fungible' component into D975 (Standard Specification for Diesel Fuel Oils), low cost biodiesel made from currently available feedstock and current processes is not suitable as a jet fuel at high altitudes where temperatures reach -50° C. In addition, due to questions associated with long-term storage over six months with biodiesel blends, the military currently has a prohibition on biodiesel inclusion at any level for fuel used in 'tactical' diesel equipment; that equipment which can be called upon at any moment for military operations around world.

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THE CHALLENGE FACING EFFORTS TO ENCOURAGE MILITARY USE OF BIODIESEL AS A "DROP-IN FUEL"

By

Rasaq A. Balogun

A Research Paper

Submitted in Partial Fulfillment of the

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Abstract

There has been a significant increase in activity with the military and the airline industry regarding the encouragement and use of so called '*drop-in renewable fuels*'. The *USDA* and *DOE* and the U.S. Military, have announced funding of over $500 million for development of '*drop-in renewable fuels*' for military and aviation use. While B5 (5% biodiesel, 95% petro-diesel) has been adopted as a 'fungible' component into D975 (Standard Specification for Diesel Fuel Oils), low cost biodiesel made from currently available feedstock and current processes is not suitable as a jet fuel at high altitudes where temperatures reach -50° C. In addition, due to questions associated with long-term storage over six months with biodiesel blends, the military currently has a prohibition on biodiesel inclusion at any level for fuel used in 'tactical' diesel equipment; that equipment which can be called upon at any moment for military operations around world.

The perception is that these two factors only (temperature and long-term storage challenges) have been the driving force behind biodiesel being overlooked as a low cost '*drop-in' fuel* for non-jet applications in the military, where commercial No. 2 petro-diesel is being used; thereby eliminating biodiesel from being eligible for government and military funding for '*drop-in' fuel*. Some would argue that current 'low bid' and special 'carve out' purchase requirements for small and disadvantaged businesses and lack of adoption of the BQ-9000 (National Biodiesel Accreditation Program) in military bid specs have resulted in quality and equipment issues by some in the military. The military currently uses B20 (20% biodiesel, 80% petro-diesel), especially the U.S. Air Force (USAF). In contrast, other military facilities have used B20 successfully for years and see it as a leading option to meet Executive Order 13149.

This Executive Order mandates the military to replace 20% of conventional fuels with renewable fuels by 2025.

My investigation says otherwise. There are other factors that have made biodiesel blends from corn and soybean largely prohibitive for use as a '*drop-in*' fuel and this research was conducted to identify those factors and present them in a clear and concise manner. Here are the additional challenges that I believe researchers will face in their effort to encourage the military to use biodiesels as a 'drop-in' fuel in tactical vehicles and weapon systems. The biomass component of the new fuel has to meet the following requirements:

1. It has to be a drop-in replacement for the petroleum-based fuel.

2. It must meet or exceed the performance requirements of petroleum-based fuel. (*There must be no notable operational differences.*)*

3. The biofuel must be successfully mixed or alternated with petroleum fuel.

4. The biofuel must require no modifications or enhancements to the configuration of the aircraft or ship or any tactical weapon systems.

5. The biofuel must require no modifications or enhancements to the Military's existing fuel storage or transfer infrastructure.

6. The biological component of the blend must not compete with food crops.

This research will focus on these six factors as the major "stumbling blocks" to acceptability for the military. *These parameters are non-negotiable.*

Acknowledgements

A lot of people were invaluable to me in the research of this project. Upon being selected to the U.S. Navy Supply Corps' 811 (Petroleum) program, I knew I was embarking on the career path of being a Fuels Officer. Little did I know that I would be exposed to a world that I knew existed, but never knew I had a chance to be a part of; still I forged ahead to the University of Kansas to acquire this knowledge without any clue of what I would learn or what I could do with it in the future. This brings me to the reason for these notable mentions.

I would like to Thank Mr. Levon "*Hank*" Carpenter, President/CEO of LNS Technology, Inc. He offered me an opportunity to shadow him for a whole summer. A true gentleman and a consummate professional; he gave me "*a corner*" to work, and to dream of the possibilities that lay ahead if I stay the petroleum and energy management course.

I would like to Thank Professor Susan Williams of the KU Biodiesel Institute for providing me the opportunity to research this project by assigning it to me. She allowed a bright eyed graduate student that she had a chance encounter with at an Energy conference, to explore an idea and in the process, I have gained immense insight to this "life enhancing" field of study.

To the NAVSUP Energy Team at the Defense Logistics Agency (DLA) Energy in Fort Belvoir, Virginia; most notably, Navy Captain Kurt Waymire (NAVSUP Energy Office), Rick Kamin (Navy Fuels Team leader), and Ms. Lynda Turner (NAVSUP Energy Logistician). I would not have been able to start or complete this research without you all taking the time to sit with me, talk to me and provide the necessary data or point of contact to assist me.

Thank you to Mr. Ben Curtis (Team Leader) and Mr. Emilio Alfaro of the Science & Technology (S&T) Division of the Air Force Petroleum Agency (AFPA). Taking the time out of

time out of your busy schedule to provide valuable insight to the challenges facing DOD and their energy needs. You do great work at the AFPA helping DOD to meet its daily energy challenges. I salute you.

To Mr. Olliver Davis, Thank you for encouraging me and listening to me during these challenging times in my life. You've been like a father to me, and I love you.

Thank you to Lieutenant Commander Elisha Grey-Singleton, my "*compadre*"; our friendship began as college students in the same Navy ROTC unit at "*Dear Old' Morehouse*". Through the years, you have grown to be an outstanding naval officer, a wonderful mother to your two daughters (Dasia & Asia), a loving daughter and a great friend to me. The past two years have especially been challenging for the both of us, personally and professionally and you have supported me, listen to me and as we wrap up this program, it is wonderful to know all those "*come to Jesus moments*" at the Quiktrip Gas Station was well worth it.

Thank you to the Brothers of Omega Psi Phi Fraternity, Incorporated; especially the members of Omicron Iota Iota Chapter (The Buffalo Soldier Ques) of Fort Leavenworth, KS. You truly epitomize the meaning of true "Friendship", real brotherhood.

Thank you to all those who have supported me, personally and professionally. There are too many to name, but you are still family. I salute you and I love you all.

Dedication

To my son, Abdul Rahman. Daddy loves you and always will. There are going to be many challenges you will face in this Hydrocarbon world, but whenever those challenges do come, and they will, this is my wish for you.

To have the courage to live your life

How you want to

Where you want to

However you choose to

Whenever you choose to

With whomever you choose to. Amen

To my Father (Rafiu B. Balogun) and my Mother (Ganiat A. Balogun). You have to both loved me and supported me unconditionally. I love you.

To the rest of my friends and family (there are too many of you all) and I am blessed to be part of yours too. Thank you and I love you.

Executive Summary

The 21st century Man is famously known as the "Hydrocarbon Man". Why is that? It is because of how much oil has permeated every facet of human life. In the 1800's, before fossil fuels became king, whale oil was used in lamps to light up the cobblestone streets, offices and homes. Due to the ecological impact the killing of whales had on the industry, it created a huge oil supply shortage. Whale oil became expensive and out of necessity, a need for a new form of oil was discovered. In 1849, a Scotsman named James Young patented a process for converting coal into *coal oil*. Before that, a Canadian geologist named Abraham Gesner researched the use of minerals resulting in 1846, the development of a process to refine a liquid fuel from coal, bitumen and oil shale. His discovery was called named *kerosene*. These energy products (*Coal Oil & Kerosene*) became the first alternative fuels to Whale oil. Coal oil and Kerosene were cheaper alternatives, but they smoked and had a bad odor. In 1857, A.C. Ferris, a lamp maker, produced a clean-burning kerosene that did not have a bad smell. And for a while, all was well, but Man's insatiable appetite for oil, population growth, and technological innovation created a demand for new forms of fuel.

Over 150 years after the first drilling derricks were erected in Titusville, Pennsylvania; Man has a renewed need to satisfy that addiction. Human's addiction to oil has intensified the research and development into new forms of alternative fuels. The challenges today are numerous and multi-layered. Unlike the driving forces of over century and half ago, profit is not just the motivation, the human races' survival depends on it. This research allows an opportunity to review this new fuels and address the misconceptions of its use (or lack thereof) within the military and the aviation community.

Table of Content

Chapter One

Introduction

Oil is the backbone of modern day life. The houses we live in, the cars we drive, is all because of oil. Oil is one of the most important commodities in the world. Oil has been extracted from the ground for over 150 years. It is the easy, economic fuel that makes the modern world possible. Over 1 trillion barrels of oil have already been retrieved from the earth. Even though it is assumed that another 1 trillion is supposed to be left; there is growing anxiety that may not be the case. The U.S. currently imports more oil than any other country in the world; China is gradually becoming the second. Every day, the U.S. produces approximately 8 million barrels of oil per day, but consumes about 19.6 million barrels of oil per day (more than doubled our daily capacity). In essence, the U.S. is more than 10 million barrels of oil short on a daily basis.

U.S. Petroleum Consumption (2010)

Year	Barrels in Millions
2010	19.15
2009	18.69
2007	20.7
2005	20.8
2004	20.73
2003	20.03
2001	19.65

In 1973, due to the Arab-Israeli conflict, an oil embargo was placed against the United States and the West. This created long lines at the pump and gas stations around the country, because these gas stations ran out of fuel. Many experts asserted at the time that this event

signified that oil production had peaked; that was over 35 years ago. With the advancement in technology in both how oil crude is explored, extracted and refined, crude oil production has increased tremendously. These technologies have caused the peak to shift, but at a steep price. The Defense Dept (DOD) announced its concerns about this 'peak oil' in 2010. "*The U.S. military cautioned that the oil production capacity could disappear within two years, with major shortages occurring in 2015*" (Kohl, 2010). It is only fitting that DOD is sounding the alarm on 'peak oil', not the *DOE*, because of DOD's heavy reliance on fossil fuel. Here are sobering facts:

- DOD spends approximately $180 billion on total energy use per year. DOD is the single largest consumer of that energy in the world.
- The U.S. Military spent $22.5 billion on fossil fuel products in fiscal year 2009, 87% of it was to purchase petroleum.
- The U.S. military consumes well over 300,000 barrels of oil *every day*

Oil is the most powerful, versatile fuel in the planet. It is made from dead plants and animals that were compressed and heated over hundreds of millions of years. It's in everything from toothpaste, lipsticks, to polyester and plastics and the Defense Dept. recognizes this importance. It is well understood the role DOD plays when it comes to America's energy security, because *America's Energy security is about America's National Security.* In the last five years, the military has been working on numerous alternative and renewable energy projects like Biomass products (like wood pellets) for the Coast Guards in Alaska; fuel cells to run on demand with unmanned area vehicles (UAV's) and in use with battery packs to service the radios and other small gadgets in the sandbox of Iraq and Afghanistan.

Today, the Navy is a 'global force' for good. This is not just an advertising slogan used in everyday television viewing, but an acknowledgement of the reality that confronts the

cornerstone of America's global defense force. At the most recent Energy Summit in Washington, D.C. the SECNAV made the following comments, "*90% of all trade for the world is conducted by sea; 95% of the world's telecommunications go under the sea and it is for this reason that the U.S. Navy is globally deplored, and that the Navy is globally engaged. Our maritime forces are incredibly flexible, extremely responsible; provide leadership for this country with an array of options when a crisis arises*" (Mabus, 2011).

This commitment to our nation's energy security required the Navy to come up with procurement specifications for all renewable/alternative fuels. In the case of biofuels, the procurement specifications specified what the performance properties for the biological components of these blended fuels. For the biomass component of the new fuel, they had to meet the following requirements:

1. **It has to be a drop-in replacement for the petroleum-based fuel.**
2. **It must meet or exceed the performance requirements of petroleum-based fuel. (There must be no notable operational differences.)***
3. **The biofuel must be successfully mixed or alternated with petroleum fuel.**
4. **The biofuel must require no modifications or enhancements to the configuration of the aircraft, ship or tactical equipment.**
5. **The biofuel must require no modifications or enhancements to the Navy's existing fuel storage or transfer infrastructure.**
6. **The biological component of the blend must not compete with food crops.** *This last parameter makes traditional materials or "feedstock" such as corn or soy not appropriate because they are a dedicated food source for human consumption.*

The U.S. Navy is unwavering on the above requirements and the Air Force is working closely with the Navy Fuels Team in helping to reach these goals. The Navy and the Air Force are taking the lead because they both combine for more than 70% of every dollar spent on petroleum products. In essence, the Navy spends 26¢ and the Air Force spends 42¢ for every $1of fossil fuel the military purchases. When it comes to the use of any alternative fuel, the rest of DOD goes as the Navy and the Air Force goes.

The focus of my paper will be directed at the requirements for the military's procurement specifications for biofuels and other biodiesel blends that pose a challenge in encouraging its use as a '*drop-in*' alternative.

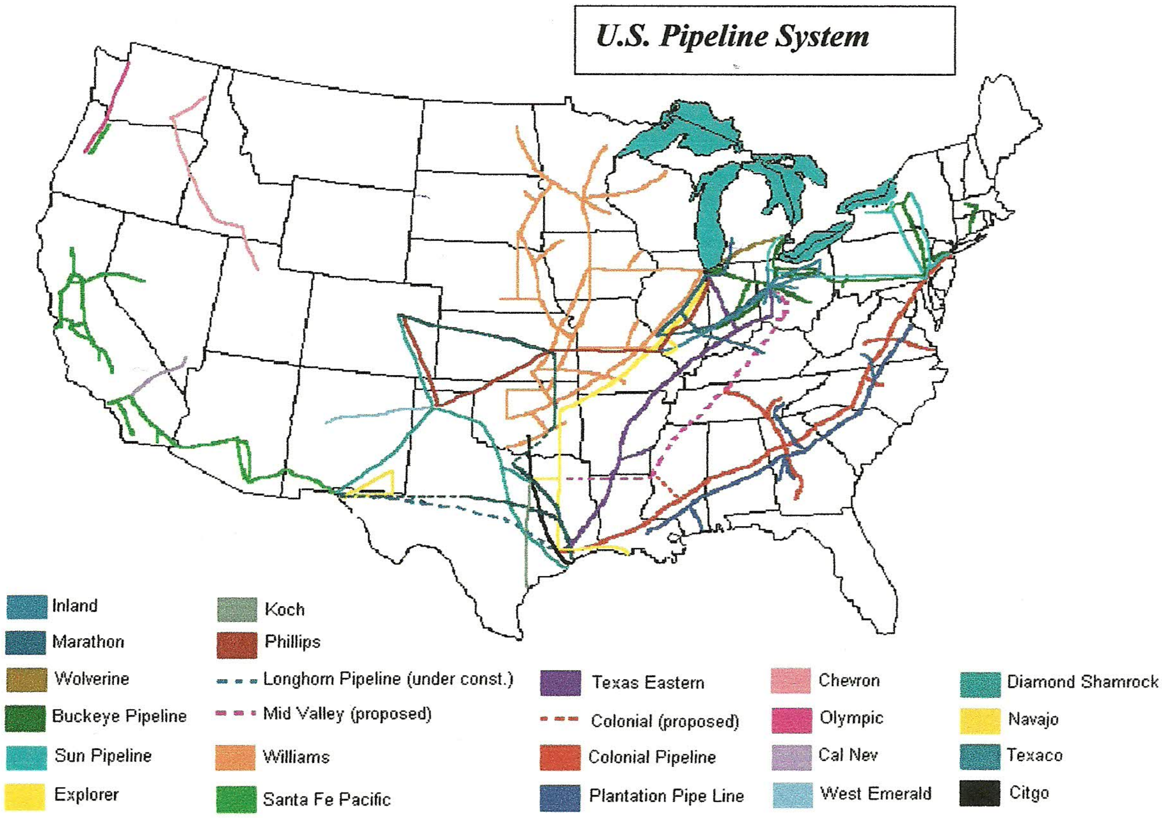
Chapter Two

Drop-In Fuels

What defines a 'drop-in' fuel? The renewable/alternative energy advocates themselves aren't exactly clear about what a 'drop-in' fuel is. Some have defined it broadly to mean any renewable/alternative fuel that makes use of at least some of the costly existing petroleum products currently available, while others have taken a more narrowed approach. The U.S. Biomass Research & Development Board (a consortium chaired by the *USDA* and the *DOE*) has defined a '*drop-in*' fuel as "*a substitute for conventional fuel that is completely interchangeable and compatible with conventional fuel. A 'drop-in' fuel does not require adaptation of the engine, fuel system or the fuel distribution network, and can be used **"as is"** in currently available engines in pure form and/or blended in any amount with other 'drop-in' neat, 'drop-in' blend, or conventional fuel.*" Energy producers need renewable sources that can be used without an additional investment in our current infrastructure, where storage and distribution has long catered to petroleum products. Since there are numerous infrastructures that can be used to address 'drop-in' fuel delivery, this research will focus on just one of them; *the U.S. oil pipeline network.* This is because of its inherent importance to the nation's energy security. In the U.S. alone, there are two types of fuel pipelines; ***oil*** and ***natural gas*** *pipelines.*

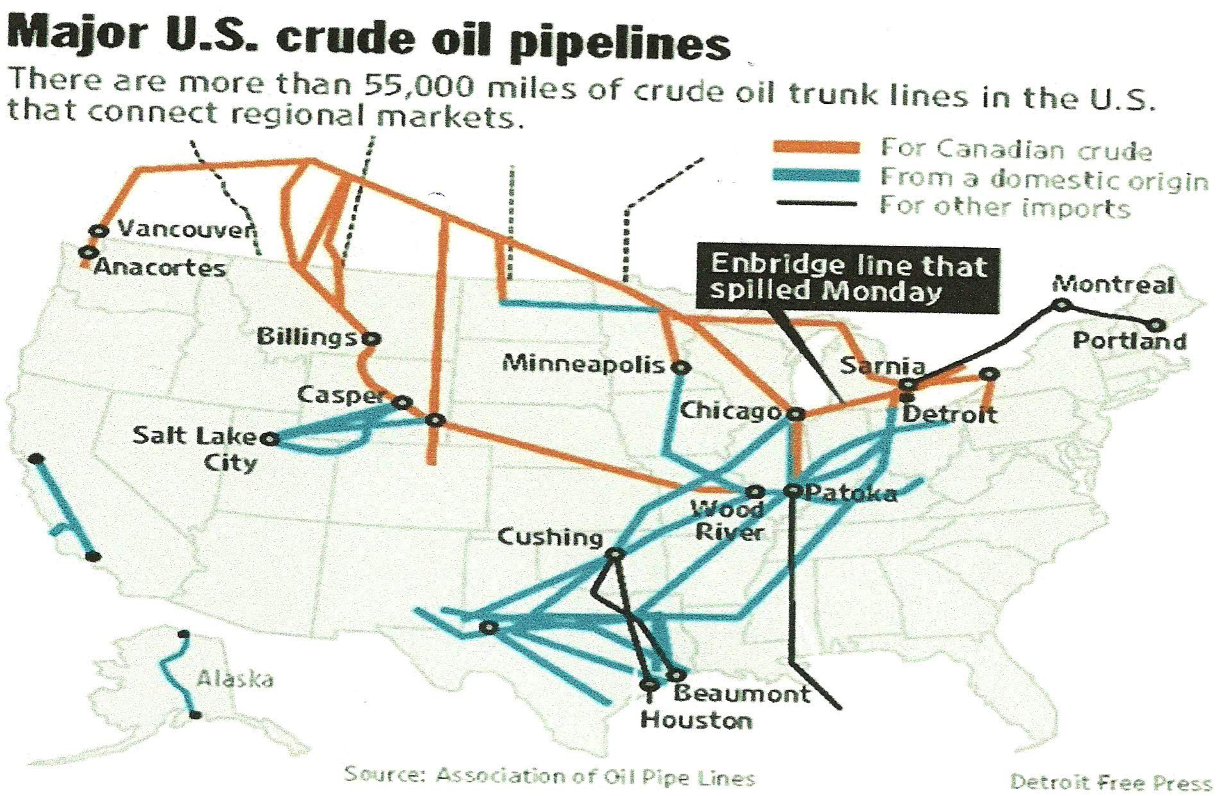
Oil Pipelines:

There are two types of oil pipelines in the U.S. There is *crude oil* and *refined product* pipelines. Crude pipelines are further divided into two subset pipelines (*Gathering* Lines and *Truck* Lines).

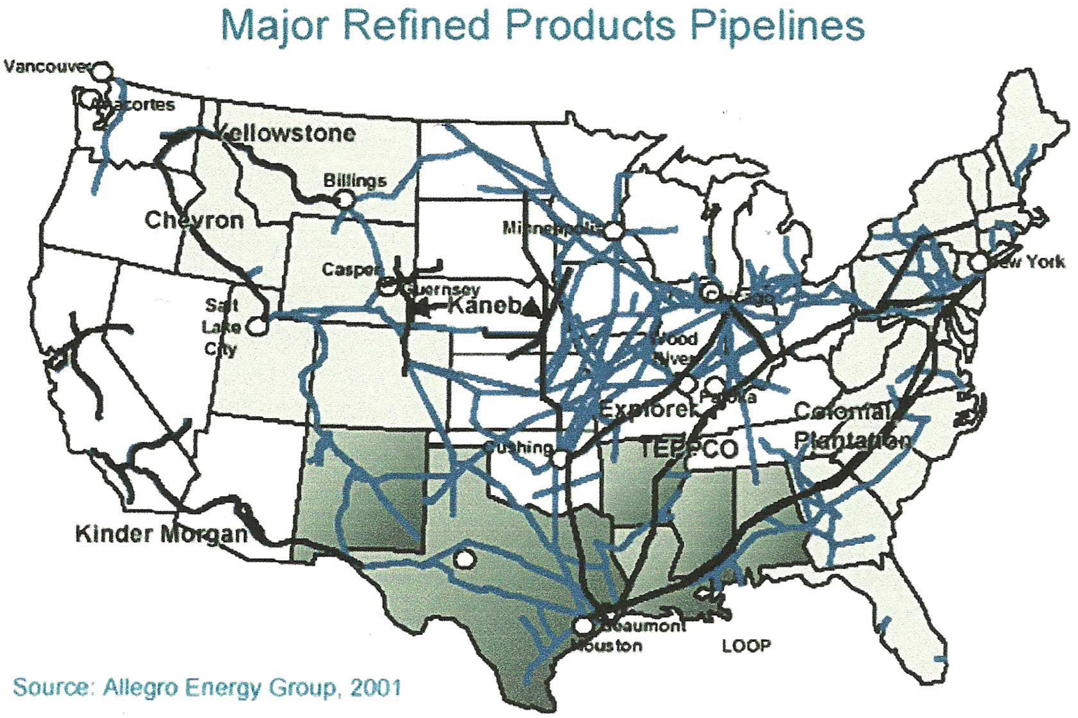


Gathering lines are very small pipelines usually from 2 to 8 inches in diameter in the areas of the country in which crude oil are found deep within the earth. "*It is estimated that there are between 30,000 to 40,000 miles of these small gathering lines located primarily in Texas, Oklahoma, Louisiana, and Wyoming with small systems in a number of other oil producing states. These small lines gather the oil from many wells, both onshore and offshore, and connect to larger trunk lines measuring from 8 to 24 inches in diameter*" (Pipeline 101, 2007).

Trunk lines are much larger lines (e.g. the Trans-Alaska Pipeline System), which is 48 inches in diameter. "*The larger cross-country crude oil transmission pipelines bring crude oil from producing areas to refineries. There are approximately 55,000 miles of crude oil trunk lines in the U.S.*" (Pipeline 101, 2007).



The next group of pipelines is the *Refined Products* pipelines that carry products like, jet fuel, gasoline, diesel fuel and military standard (Mil-Spec) fuel, just to name a few. Refined product pipelines vary in size from relatively small 8 to 12 inch diameter lines up to 42 inches in diameter. These pipelines are found in almost every state in the U.S, with the exception of some New England states. "*The total mileage nationwide of refined products pipelines is approximately 95,000 miles*" (Pipeline 101, 2007). These pipelines deliver petroleum products to large fuel terminals with storage tanks to be loaded into tanker trucks. Trucks cover the last few miles to make local deliveries to gas stations and homes. Major industries, airports and electrical power generation plants are supplied directly by their pipeline network.



Natural Gas Pipeline:

Natural gas pipeline systems are organized differently from crude oil pipelines. Natural gas, unlike oil, is delivered directly to homes and businesses through pipelines. Natural gas is found in many of the same areas of the country as crude oil and is collected through small gathering systems and moved to gas processing plants, where impurities are removed. There are about 20,000 miles of natural gas gathering lines. The gathering lines move natural gas to large cross-country transmission pipelines; including both onshore and offshore lines. "*There are approximately 278,000 miles of natural gas transmission lines*" (Pipeline 101, 2007). Natural gas is then delivered directly to homes and businesses through local distribution lines. Large distribution lines, called mains, move the gas close to cities. These main lines, along with the much smaller lines to homes and businesses, deliver natural gas under streets in almost every city

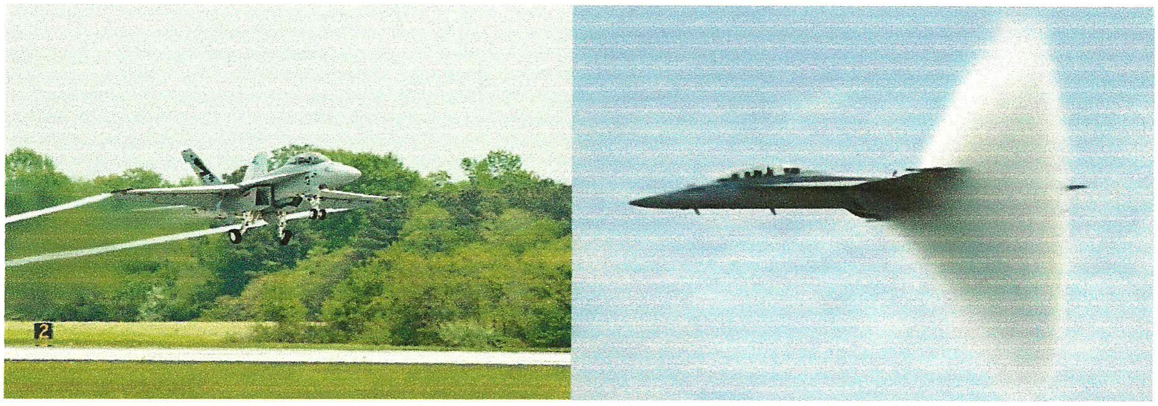
and town and account for the vast majority of pipeline mileage in the U.S., up to 1.8 million miles.

The investment in the current pipeline infrastructure in the U.S. is not a small feat. The annual expenditure outlay for the maintenance of all these various pipelines (both oil & natural gas) is over $7 billion alone each year. For crude oil pipelines; "*replacing pipelines is a very expensive pastime (up to $50 million for every 100 km or approx. 62.14 miles)*" (Greasby, 2006). In essence, to retrofit, upgrade, and adjust to accommodate the use of biodiesel blends that are non-drop-in fuels will cost approximately $76.4 billion for every inch of that pipeline. When you add the annual cost of yearly maintenance, the numbers begin to add up very quickly, thereby out-running the benefits of using biodiesel blends (even B20). Experts say in other to keep servicing the end-user without passing the hefty burden on them at the pump or their utility bills, the use of biodiesel blends must be done judiciously. Hence, it is important to keep these pipelines well maintained and corrosion-free, in other not to interrupt the flow of oil. Any alternative fuel that requires a new set of pipeline construction adds a higher premium to the use of that fuel, and that cannot be economical.

Chapter Three

Challenges of mixing blends with Petroleum Fuel

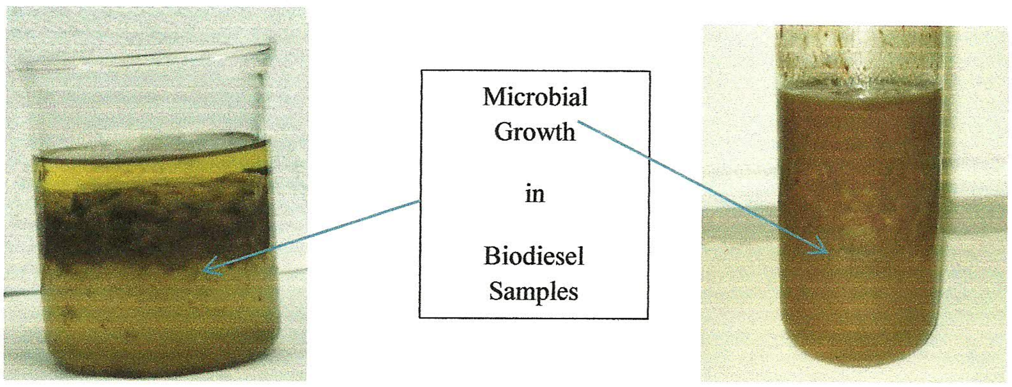
As *the world celebrated the* 40th Anniversary of *Earth Day;* marking four decades at the forefront of the environmental and climate change movements, the Navy was making its mark by re-writing aviation history. "*What appeared to be a routine flight of a Green Hornet-the F/A 18 E/F, the Navy's premier fighter jet - attracted hundreds of onlookers, including the Secretary of the Navy Ray Mabus. This time for the first time, the jet was powered with 50/50 blend of biofuel and petroleum-based fuel*" (Currents, 2011). This is a first for aviation history that an aircraft (civilian or military) would fly faster than the speed of sound on a fuel mix that is 50% derived from biomass. The success of this flight test was the culmination of a road that started in 2008, when the Navy Fuels Team began testing small quantities of biofuels in a Laboratory located at Naval Air Station, Patuxent (PAX) River, MD. In our nation's pursuit of energy security, this accomplishment is a great leap forward. It has shown the way to bridge the gap to lower energy cost, at the cost of millions of dollars spent on R&D. It also helped to identify the enormous challenges that were faced by this project, while highlighting many more that still remain.



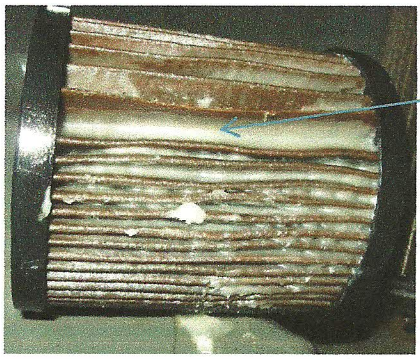
U.S. Navy's Green Hornet *takes flight during a test demonstration and breaking the sound barrier using 50/50 bio-fuel. PATUXENT RIVER, Md. (April 22, 2010)*

The truth of the matter is, the use of biodiesel blends by the military in jet aircrafts, tactical vehicles and other weapon systems has come at an exorbitant price tag to the taxpayers. The military's researchers in fuel technology have embraced the use of biodiesel blends like B20 in testing their tactical vehicles, not because they want to and like the results they are getting, but because they are mandated by congress to do so. According to some of these military experts, if they could have their way, they would scrap the use of all biodiesel blends for military use in tactical vehicles and weapons systems, period. Here are the reasons why:

- Most Biodiesel blends have low temperature properties that make them off limits for use as a jet fuel. Any type of fuel with more than 5 parts per million (ppm) in it is considered an "*incidental contaminated*" fuel. This is a problem in all mechanical engines of all types, especially in jet engines.
- Most Biodiesel blends are found to be unstable. They break down easily when subjected to various temperature/pressure variances.
- Microbial growths have been found in some of these tanks that contained biodiesel blends. This is because biodiesel is easily metabolized by fungi and microbes
  - Several samples of B20 the AFPA received contained no biodiesel at all as a result of fungi metabolizing the biodiesel content first



- Most Biodiesel blends; due to their instability have caused million dollars' worth of damage to mechanical equipment. The military's fuel testing laboratories are littered with Fuel filters, injectors, tanks clogged with orange-brown deposits.



These motor filters appear to have been rubbed with lard. This is as a result of testing using 30gallons of B20 at this Military Laboratory. These several pounds of solids are called Plugging.

The USAF's Science and Technology (S&T) Division were the first to start investigating various cases of B20 cold weather fuel filter plugging. In October 2009, the Air Force Petroleum Agency (AFPA) directed the sampling of every B20 tank bottom with a Bacon Bomb Sampler. The various Air Force Bases involved with the project were instructed to submit any B20 fuel samples that were not clear and bright to the AFPA. The decision to verify these samples was based upon an unusual tank bottom seen at Air Force (AF) bases in the southern U.S., during the winter of 2009. In all, 19 USAF bases submitted samples from 21 tanks and the results were eye opening.

These samples were typical for Bases where fuel filter plugging

Nozzle Sample

Bottom Sample

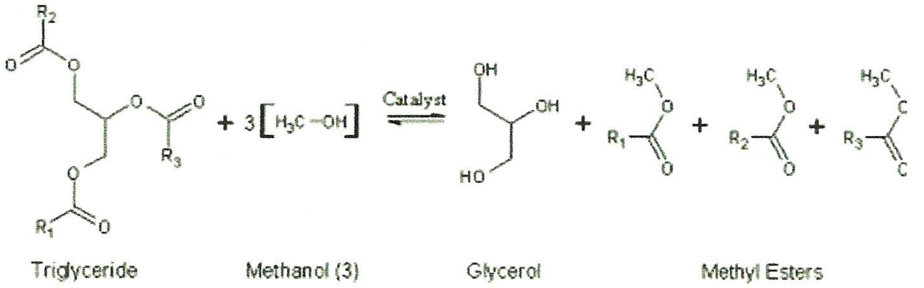
The bases that reported the hazy tank bottoms experienced fuel filter plugging, when colder weather arrived. The deposits were due to the degradation of B20 fuel. Some of the other samples of the tank bottoms also contained microbial growth (evidence of the existence of moisture), even though none of the hazy samples had excessive water in it. Nevertheless, further analysis was conducted to determine the contents of the "bottom tank" samples. It was determined that the haziness was caused by trace components in the B20, which were concentrating in the bottom of the tank.

The chemical analysis of the hazy tank bottoms showed the following chemical compounds that existed as solids and their melting points (MP):

- Cholesterol (MP = 299° F): Indicative of animal fat feedstock
- Plant Sterols
  - Sitosterol (MP = 279°F)
  - Campesterol (MP = 315°F)
  - Stigmasterol (MP = 338°F)
- Glycerides
  - Monopalmitin (MP = 167°F)
  - Monoolein (MP = 97°F)
  - Tocopherol (MP 235°F), a biodiesel anti-oxidant
- **Long Chain Saturated FAME**: The biggest issue that the USAF researchers were concerned about regarding biodiesel blends is the "*oxidation stability*" of biodiesel blends (or fatty-acid methyl esters, FAME problem). This problem is *the most important issue that is causing the restrictive use of biodiesel blends* and it warrants being addressed separately.

Oxidation Stability of FAME

"*Biodiesel is an alternative diesel consisting of alkyl monoesters of fatty acids from vegetable oils or animal fats. The unsaturated fatty acid chains in biodiesel are susceptible to oxidation, and the mechanism is well known*" (Tang, Guzman, Salley, & Ng, 2008). In the science of biodiesel production, Trans-esterification of vegetable oils with methanol produces the methyl esters of the fatty acids (together with glycerol as a byproduct).



Trans-esterification of triglycerides with methanol

These have only a limited shelf-life as they are slowly "*oxidized*" by atmospheric oxygen. The resulting oxidation products can cause damage to combustion engines. This is why "*oxidation stability*" is an important quality issue with biodiesel, which needs to be regularly determined during production.

These FAME compounds were also identified in the hazy tank bottoms:

- Methyl arachidate (C20:0) (MP = 130°F)
- Methyl behenate (C22:0) (MP = 129°F)
- Lignoceric acid methyl ester (C24:0) (MP estimated @ 130°F)

The National Renewable Energy Laboratory (NREL) have reported that Lignoceric acid methyl ester (C24:0) FAME occur in tallow and lard, while Methyl arachidate (C20.0) and Methyl behenate (C22:0) occur in palm, peanut, sunflower, ***soybean***, rapeseed, tallow, and lard. The DOD uses a lot of soybean-based B20 in its fuel research, so it is no surprise that these types of contaminants were found in heavy amounts. While the presence of these FAME in the tank

bottoms are not conclusive, their melting points suggest the potential to fall out of solution during cold weather and long periods of storage causing fuel filter plugging.

For biodiesel blends like B20 to be heavily used as an application in military tactical vehicles, the ***oxidation stability problem must be solved***. The orange-brown deposits found at the bottom of fuel tanks, in injectors, fuel lines and filters are as a result of *oxidation stability of FAME*. In other for the military and the aviation community to be fully accept biodiesel blends as a viable alternative, the processing of these blends must be taken one step further. If the oxidation stability is the problem, "*Hydro-treated Renewable*" blends may be the answer.

<u>Hydro-treated Renewable Blends</u>

Hydro-treated Renewable (HR) blend is a "*term used to describe any feedstock or process that leads to fuel that is chemically identical to crude oil-based kerosene*" (Decker, 2010). Hydro-treated Renewable fuel is a refinery process that injects hydrogen into the biodiesel blends in other to eliminate the oxygen content of those fuels. Military fuel technicians insist biodiesel blend not be procured on their behalf "as is", but as a product that has been refined further into hydro-treated renewables. This further refined biofuels is more acceptable for use in military tactical vehicles and other equipment. With hydro-treated renewables, aviation experts are convinced they can use up to 50% blends of hydro-treated renewable blends with petroleum-based fuels. The benefits of hydro-treated renewable blends are:

- Highly stable
- Environmentally friendly
- Carbon Neutral, due to reduction in particulate emissions
- Cetane number and thermal stability should be superior to typical conventional military fuels

It seems the future of biodiesel's successful military application may rest in hydro-treated renewable fuels, because of the cost of production. Even though the data is not readily available, information that is available suggests that hydro-treated renewable fuel can be produced from vegetable oil at a cost of roughly $0.30 to $0.45 per gallon. At today's prices for soybean oil priced at $3.07 per gallon, it is estimated that hydro-treated renewable diesel (using soybean or corn) would cost between $3.40 and $3.55 per gallon at the refinery gate, excluding consideration of federal subsidies. "***At these production costs, hydro-treated renewable fuel production starting with soybean oil is not economical unless world oil prices are in the range of or above $110 per barrel***" (Bartis & Van Bibber, 2011).

Chapter Four

Equipment Modification or Enhancement is prohibited

The *Pentagon* is going through a period of restructuring across the board. The "*build-down*" in military spending for fiscal year 2012 and beyond will be done gradually over the next 10 years. This includes a reduction in personnel & manpower, and procurement of equipment and other weapon systems. The plan that was pushed by the Obama Administration was to reduce military spending by 30% within a decade. Part of the way of accomplishing this is via a reduction in the procurement of weapon systems. According to some national security experts, procurement will take the hardest hit, because it is anticipated that due to the conclusion of two wars (in Iraq and Afghanistan), the need for heavy weapon equipment deployment is greatly reduced. This will have real implications for the next generation of weaponry and warfare. The military has done a good job with equipment modernization in the last 10 years. "*The Army upgraded substantial portion of its hardware; the Navy bought nearly everything on its long range plan from 2000 and the Air force bought a lot of F22s, Unmanned Aerial Vehicles (UAVs), and C17s*" (Adams, 2011), and there are no plans for any additional purchases of new weapons in the near future.

The DOD's future plans for energy consumption will be done with current assets available. Even SECNAV echoes similar sentiments in a speech late last year, when he said: "*We can develop alternative fuels... We can use a domestic, renewable feedstock that's stable, has price stability, but somebody's got to bridge the so called "valley of death" from R&D...to production, affordable, competitive, volume production.* ***We almost have to do this. And we have to do it in a way that will work in existing engines, we're not going to change the engines that we've got in our ships or our planes or vehicles****, and it's got to work in a way that doesn't harm the food supply, doesn't take food off anybody's table*" (Mabus, 2011).

Simply put, the successful use of biodiesel in today's military weapon system must not require any modification or enhancements to the configuration of that equipment. Some of the weapon system that is used is uniquely designed for U.S. military use "only" and it comes at a huge price tag to the American taxpayer. On the low end of that price range is the world renowned HMMWV assault vehicle popularly known as the "Humvee". The unit cost of a Humvee (Unarmored) is $65,000 and can rise up to $145,000 (fully armored), while on the high end of the spectrum is the Navy's newest class of amphibious transport ship, the USS San Antonio class (LPD 17) whose unit cost is approximately $1.7 billion. These two weapon systems may be as apart as far pricing is concerned, but they use the same type of fuel. Any modification or enhancement to these equipments in other for it to use a biodiesel blend would register an additional cost to the taxpayers and will require modification to every weapon system in our military catalog. In the coming era of military "*build-downs*" and the U.S. economy still sputtering to a recovery, any biodiesel blend that is less than compatible with the tactical weapon systems in our inventory is a non-starter.

Unit Cost of Select Military Tactical Weapon Systems

Equipment	Unit Cost
U.S. Navy's F/A 18 Hornet	$27-$57 million
USS G.W. Bush (CVN 77)	$6.2 billion
USS San Antonio (LPD 17)	$1.7 billion
U.S. Marine Corps' A/V 8B Harrier	$24-30 million
U.S. Air Force's F-35 Lightning	$237.7 million
C-130 Hercules (All services)	$62 million
HMMWV "Humvee" (All services)	$65,000 (Unarmored); $140,000 (Armored)
USAF C-17 Globemaster III	$218 million
USAF F-22 Raptor	$150 million

Chapter Five

Fuel Storage or Transfer Infrastructure Modification or Enhancement is prohibited

The Defense Logistics Agency (DLA) Energy is the DOD component that oversees all services worldwide energy operations. DLA Energy's mission is to provide DOD and other government agencies (federal, state or municipal) with comprehensive energy solutions in the most effective and efficient manner possible. This includes the management and maintenance of DOD Energy facilities around the world. DOD's assertion not to modify or enhance fuel storage facilities is rooted in the investments that have been made in the development of the most extensive worldwide distribution and supply chain network from the storage facilities to the warfighter on the battlefield. This complex infrastructure has serviced this nation successfully for many years through numerous conflicts and it has been the backbone of this country's national security. Below is an executive summary on DOD's expenditures over the last three fiscal years.

DLA Energy Summary

US Dollars	FY 2008	FY2009	FY2010
Purchases at Cost*	$19.36 billion	$12.14 billion	$14.93 billion
Net Sales **	$17.77 billion	$12. 11 billion	$15.36 billion
Ending Inventory* **	**$8.96 billion**	**$4.47 billion**	**$5.58 billion**

- *These are the expenses for petroleum, natural gas, aerospace energy, federal excise tax, transportation, facilities, DLA Energy operations and headquarters.
- **These are the net sales for petroleum, natural gas and aerospace energy.
- ***These are the petroleum and aerospace energy inventory.

The focus of this chapter will be the storage and distribution services provided by DLA Energy.

Energy Storage Facilities

DOD Storage facilities are like any other facility that is owned by any private or public company. And like any facility, the true cost of ownership is in the operation and maintenance of these facilities. For DOD, the maintenance of facilities (Energy and otherwise) is done under the SRM program. SRM means *Sustainment, Restoration and Modernization.*

Facilities Sustainment is the *maintenance* and *repair* activities necessary to keep an inventory of facilities in good working order. This includes regularly scheduled maintenance and major repairs or replacement of facility components (usually accomplished by contract) that are expected to occur periodically throughout the life cycle of facilities.

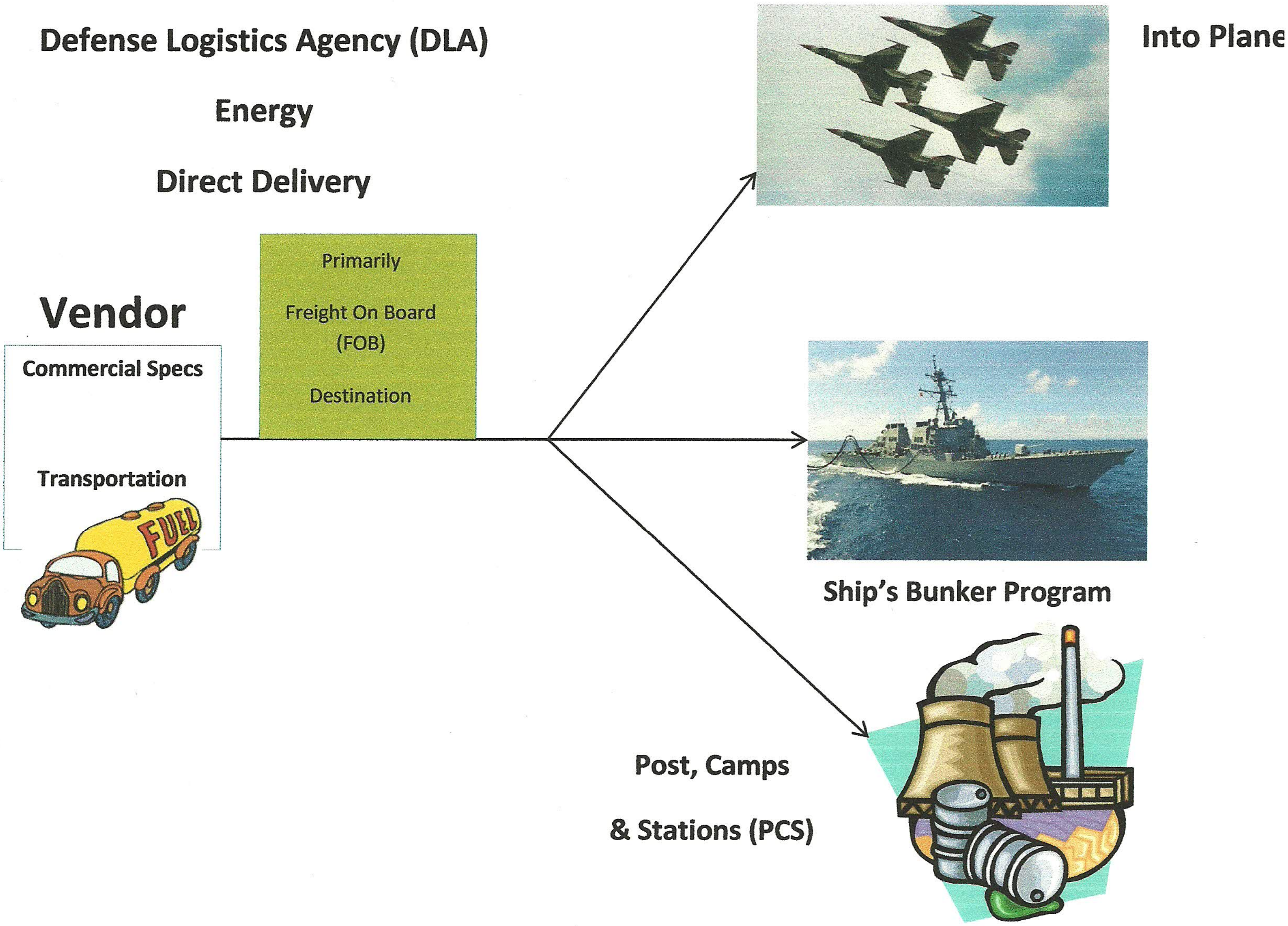
Facilities Restoration & Modernization is the improvement of facilities. *Restoration* includes replacement work to restore facilities damaged by inadequate sustainment, excessive age, natural disaster, fire, accident, or other causes. *Modernization* includes alteration of facilities solely to implement new or higher standards, to accommodate new functions, or to replace facilities that typically last more than 50 years.

The *SRM* program is funded wholly by DLA Energy for the global services fuel infrastructure to assure the readiness of DOD fuel assets. The costs are funded through the *Defense Working Capital Fund* (DWCF) and are recovered through the standard price of fuel. The standard price of fuel is a tool that was created by DOD's fiscal managers to insulate the Military Services from the normal ups and downs of the fuel marketplace. It provides the Military Services and the Office of the Secretary of Defense (OSD) with budget stability despite the commodity market swings, with gains or losses being absorbed by a revolving fund known as the Defense Working Capital Fund (DWCF). The current standard price of fuel to the Defense

Dept. is north of $125 a barrel (a barrel of crude oil futures is currently trading at $104.67 per barrel). The current annual budget for SRM in fiscal year 2011 is $305 million and it is expected to rise to $690 million by fiscal year 2015. The SRM program provides worldwide management and logistical assistance to approximately 500 installations in other to ensure that they are in compliance with federal, state and foreign requirements.

<u>Energy Transportation, Delivery and Distribution Network</u>

DLA Energy's distribution chain is funded for 179 world-wide terminals. This includes:



DLA Energy's SRM Programs

- Alongside Aircraft Re-fueling in 26 locations with an average annual value of $35.4 million
- Optimization projects: whether it is a "contractor-owned and operated" (COCO) or "government-owned and contractor operated" (GOCO), these are projects that provide annual savings of over $96.7 million
- Into-Plane Contracts domestically in 350 locations with contract value of $1.2 billion (approximately 9.8 million barrels); internationally in 156 locations and 96 countries with a contract value of $1.1 billion (approximately 10.7 million barrels)
- Ship's Bunker program domestically in 130 ports supported with contract value of $500.5 million (approximately 5.8 million barrels); internationally in 99 locations and 50 countries with a contract value of $1 billion (approximately 11.5 million barrels)
- Post, Camps and Stations (PCS) domestically in 1,742 activities supported with contract value of $2.4 billion (approximately 24.5 million barrels); internationally in 281 activities and 37 countries with a contract value of $3.7 billion (approximately 28.8 million barrels
  Aside from contracts that are awarded, the average annual expenditure to maintain this distribution chain is $363.73 million annually.

Chapter Six

No competition with Food Commodities

The Defense Dept. has long understood what impact fuel prices have on food prices. As fuel prices increases, it also increases the *standard* cost of fuel for the military. The *Standard Price* is the product cost set by the Office of Management & Budget (OMB) and the Office of the Secretary of Defense (OSD). It allows for efficient budgeting, because it lets DOD make future market projections. In the case of fuel cost, the current *standard* price of petroleum to DOD is north of $125 per barrel; even though the actual current price of sweet crude in the market place is between a price range of $103-$105 per barrel. DOD is able to budget for fuel cost without worrying about the constant volatility of crude oil prices in the stock market. This standard price already represents a burden to the American taxpayers "as is". As crude prices continue to rise, it is widely known that the cost of food commodities will rise too. Critical among those food commodities are staple crops like corn, soybean and other cereals. To understand the impact of this domino effect fuel prices have on certain staples, here is a list of additional uses of corn and soybean:

- **Corn Uses**: Eaten as "corn on a cob" and as kennels; other food combinations are soups, stews, casseroles, fritters, cornmeal, corn flour, corn bread, corn oil, corn syrup, just to name a few.
- **Soybean Uses**: Eaten as tofu, soy milk, soy oil and livestock feed

As price increases for these staples domestically, the price of byproducts from their "other uses" also increases. The addition of corn and soybean as an "*energy*" feedstock just adds to that burden for Americans and the international community.

DOD also realized that in other to combat its energy consumption, it must do everything it can to relief "*John Q. Taxpayer*" of the added burden of maintaining a strong military by not taking food from *his* table. DOD has made the declaration that when making a request for a source of renewable energy "*...the procurement specification will stipulate that the biological component of the blend **must not compete** with food crops. Traditional materials or "feedstock" such as corn or soy are not appropriate*" (Currents, 2011). The Dept. of Defense is looking for a dedicated energy feedstock, period.

Soybeans Monthly Price - US Dollars per Metric Ton

Soybeans Daily Price

$512.38

A 46% increase since Feb 2007

Food prices have been going up for a number of years and the continued upward trend in global corn, soybean and other cereal prices reflects a combination of the following factors:

- Global stocks are low by historical standards, exacerbated by drought-related production shortfalls in Argentina and the United States. Grain (corn) inventories in the U.S., the world's #1 exporter, are at their lowest levels in 30 years.

- Price pressures also remain due to uncertainties about the levels of Chinese imports in 2011 and the outlook for the new corn crop in the U.S.
- **Higher crude oil prices increase the demand for corn-based biofuel production, and** higher sugar prices have increased the demand for corn-based sweeteners.

There is a reason why Petroleum and certain food commodities are not part of the Federal Governments calculation of the U.S. Gross Domestic Product (GDP). The GDP is the amount of goods and services produced in a country within a time period. Petroleum, corn, and soybean products are considered global commodities and all production of these commodities; automatically goes into the global stock. The U.S. is a top producer and exporter of Corn (Number #1) and soybean (Number #2, behind Brazil). Despite these top rankings, the U.S. has had some challenges with the sustained production of corn and soybean, especially in Kansas.

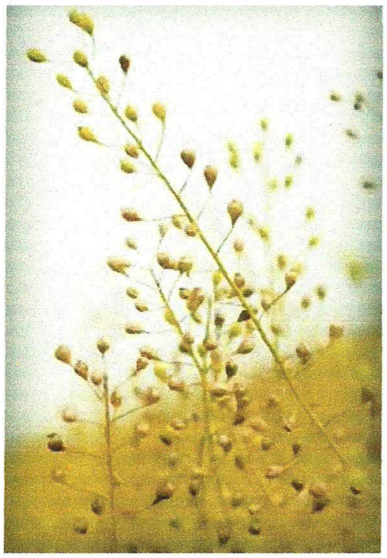
In the State of Kansas, even though **corn** production was up 5% from November 2011 forecast (449.4 million bushels); it is still 23% less than 2010 crop production levels. This was the lowest Kansas corn production since 2006 crop production (345 million bushels). In the case of soybeans, according to the USDA "*Production of* ***soybeans*** *in 2011 (101.3 million bushels) is down 27% from last year's production (138.1 million bushels). This was the lowest soybean production in Kansas since 2007*" (White & Prickett, 2012). The use of corn or soybean as an 'energy' feedstock will create additional pressure to the current global supply of these grains. DOD is mindful of this and is adamant about not subjecting the U.S. consumers to that burden, by the military's demand for fossil fuel. As steps are being taken to aggressively find the "silver bullet" solution to our energy challenges, the use of corn or soybean in the renewable/alternative as part of the solution should be done with "caution". This type of solution can easily create a bigger, longer term problem called "*human hunger*". It will create a problem on a global scale.

Chapter Seven

Camelina Sativa

Brief History

The oils that come from crushing the camelina seed (a type of mustard plant) are structurally more similar to petroleum than other bio-based products. Used by the ancient Romans as lamp oil, camelina oil was produced in Europe and Asia throughout the 19th century for a variety of industrial applications. After World War II, the crop fell out of favor and has been largely used as a minor non-food crop in Europe and a weed in North America.



Camelina Sativa

"***The World's first dedicated energy feedstock***"

When DOD started on the renewable/alternative energy road, a number of biodiesel options were researched and considered. "*Although, they were looking for a sustainable plant and/or algae-derived oil that were not competitive with food crops, it was not specified that it needed to*

be a camelina-based fuel, but camelina seemed to be the logical choice" (Currents, 2011). The advantages of camelina are the following:

- It is best grown in rotation with dry-land wheat during the part of the cycle where the land would otherwise lie fallow (uncultivated).
- Camelina does not compete with food crops
- It requires little irrigation
- Camelina has been shown to enhance the yield of subsequent crops by up to 15%
- Camelina oil is more cold-tolerant than other biodiesel feedstock

With all these benefits, it seems like "*Camelina is the world's first dedicated energy feedstock*" (Currents, 2011). Camelina seeds typically contain more than 35% oil and are high in omega three fatty acids. This has made the energy crop a good fit for jet fuel (as well as biodiesel), but the meal is also a valuable co-product as a good option for livestock feed. The major downside to camelina is, it doesn't taste very good. That is why it's never entered the agricultural mainstream. So because camelina fits so well into crop rotation, it offers farmers an opportunity to make money during a non-cultivating season. It can be harvested using the same equipment in use today by farmers.

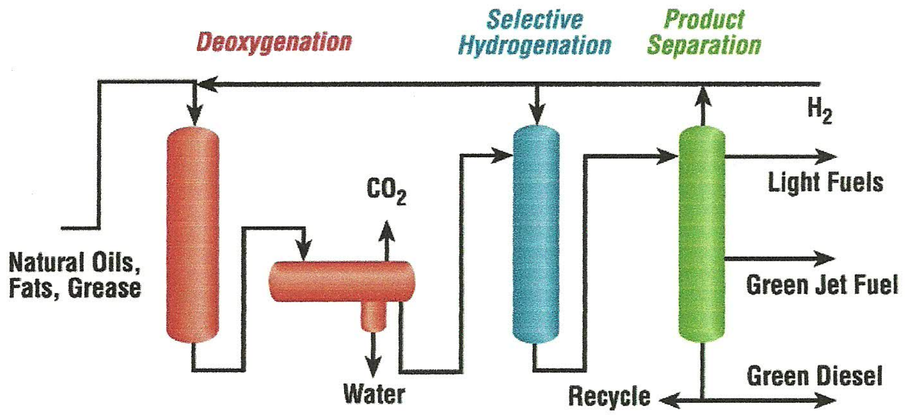
From Mustard seed to Jet fuel

The original intent for camelina oil was for use in diesel engine vehicles. For use in jet engines, the oil had to be refined into Hydro-treated Renewable (HR) fuel. In a process developed by UOP, LLC (a Honeywell Company), it utilizes traditional refinery hydro-processing technology.

First, the (Camelina) oils are cleaned to remove impurities using standard oil cleaning procedures. The oils are then converted to the shorter chain diesel-range paraffins (chemical compounds that consist of hydrocarbons and hydrogen). The process is called "*Green Jet Fuel Production Process*". This hydro-processing process (also known as De-oxygenation) converts natural oils by removing oxygen molecules from the oil and converting olefins to paraffins by reaction with hydrogen. The removal of the oxygen atoms raises the heat of combustion of the fuel and the removal of olefins increases the thermal and oxidative stability of the fuel.

A second reaction, called Selective Hydrocracking, then isomerizes and cracks the diesel-range paraffins, breaking them down into smaller paraffins with carbon numbers in the jet range. This important stage (and process) is what current biodiesel alternatives need to go thru, if they will ever be used as a jet fuel.

The third and final product separation phase separates the products of the hydrocracking process into end products like (1) light fuels, (2) green jet fuels and (3) green diesel. The end product is a synthetic paraffinic kerosene fuel that contains the same types of molecules that are typically found in conventional petroleum-based jet fuel.

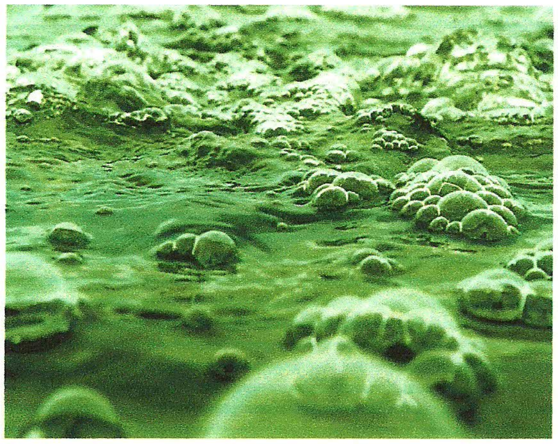


UOP's Green Jet Fuel Production Process

This process of refining has gained a gradual following within military circles as the way of the "immediate" future on how to solve the military's energy problem. This process addresses a number of issues upfront:

1. It meets and in some cases exceeds the Navy's procurement specification
2. The 50/50 blend (renewable product to petroleum) provides the necessary aromatics required in today's jet engines.
3. The process can be utilized to convert a wide range of non-food feedstock including *camelina, jatropha* (currently the oil from *jatropha curcas* seeds is used for making biodiesel fuel in the Philippines and Brazil, where it grows naturally and in plantations in the southeast, north, and northeast of Brazil) and *algae*.

Jatropha Curcas



Algae Pool

What makes this hydro-cracking process a phenomenon is, it's a process that currently exist using non-food products current and abundantly available. Researchers love it because it "*is a feedstock-agnostic, meaning that producers can select the ideal feedstock depending on their location, availability or cost*" (Currents, 2011). The future of renewable energy is already here.

The real challenge now is the seamless mass production of this product to effectively displace fossil fuels as the primary energy source within DOD and the U.S.

Conclusion

"In October of 2009, when I first announced the energy goals for the Navy, the price of a barrel of oil was $76. Now that price has fluctuated since then from a low of $71 up to a high of $117, down to the current price of $105 that we're paying, in the military, for a barrel of oil. Every $1 increase in the price of a barrel of oil costs the United States Navy $31 million in additional fuel cost. And so this range, this $71 to $117, that's a $1.1 billion range in budgeting uncertainty. And in this, or really in any budget climate but particularly in this one, that's just an unacceptable level of uncertainty. We in the Defense Department are looking everywhere to find ways to save money while maintaining the strongest military in the world" (Mabus, 2011). This was the declaration made by SECNAV at a Washington D.C. area Energy Summit. The development of the new Green Jet Fuels represents the beginning of a viable bio-fuel with the ability to challenge the current king (fossil fuel) for its crown in the Energy domain.

To show the viability of this Hydro-treated Renewable (HR) fuel, the Navy plans to sail a demonstration of the '*Great Green Fleet*'. "*These exhibitions will culminate in 2012 with a Green Strike Group of U.S. Navy ships operating locally and by 2016 deploying a Great Green Fleet powered entirely by alternative fuels*" (NAVSEA Command Public Affairs, 2010). The military especially the Navy and the Air Force are very serious about the need for these biofuels. They will not under any circumstances use any blends of biodiesels in their tactical vehicles and weapon systems, because of the numerous damage they have caused during various testing. The Navy and the Coast Guards will not step near any biodiesel blends and have restricted their use on all naval ships or Coast Guard cutters. The damage to equipment and the unpredictable nature of their use make them an instant liability for these branches. The additional maintenance cost of the current delivery infrastructure makes the full blown switch to biodiesel blends an even more expensive proposition.

It is understood that "*replacing pipelines is a very expensive pastime (up to $50 million for every 62 miles)*" (Greasby, 2006). The greatest concern of all for the military when it comes to the use of biodiesel blends is the competition with feedstock used for human consumption. The exorbitant price tag in maintaining the most powerful military force in the world is enough of a burden for the American people. The Defense Department will do everything in its power not to add to that burden by influencing food prices of common food staples like rice, corn, or soybeans. With the high price of fuel and food commodities in a struggling economy, the U.S Defense Department will do its part to reduce that burden on its citizenry. In addition to the temperature instability and the challenges of long term storage, these and other factors covered in this research have also been the main reasons the military is "cold" on the use of any biodiesel blends in their tactical vehicles and weapon systems. If the military holds fast to these guidelines, without any additional political pressure, all biodiesel blends from staple food commodities like corn or soybean ***will not*** be used as an energy feedstock, under any circumstances.

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